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Arrangement and method for iterative channel impulse response estimation

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ARRANGEMENT AND METHOD FOR ITERATIVE CHANNEL IMPULSE  
RESPONSE ESTIMATION

5 **Field of the Invention**

This invention relates to systems employing transmission channels, and particularly (though not exclusively) to wireless cellular telecommunication systems.

10

**Background of the Invention**

In the field of this invention it is known that the  
15 receiver performance in wireless cellular telecommunication systems relies on the estimate of the impulse response of the overall channel which includes the transmitter pulse, the radio channel, and the receiver selectivity filtering.

20

From the publication "Iterative channel estimation using soft decision feedback", by Magnus Sandell et al., Global Telecommunications Conference, 1998. GLOBECOM 1998. The Bridge to Global Integration. IEEE, Volume: 6, 1998, pp.  
25 3728 -3733, iterative channel impulse response estimation is known using soft decision feedback. In this known technique, channel impulse response estimation is improved through an iterative process which increases the number of known symbols in a received modulated signal by  
30 iteratively feeding back successive tentative decisions from an equaliser to a channel impulse response estimator.

However, this approach has the disadvantage that a great part of the complexity of the technique depends on the complexity of the equalizer, which may dramatically  
5 increase with the number of points in the modulation constellation.

A need therefore exists for iterative channel impulse response estimation using noise estimate wherein the  
10 abovementioned disadvantage may be alleviated.

#### Statement of Invention

15 In accordance with a first aspect of the present invention there is provided an arrangement, for iterative channel impulse response estimation in a system employing a transmission channel, as claimed in claim 1.

20 In accordance with a second aspect of the present invention there is provided a method, for iterative channel impulse response estimation in a system employing a transmission channel, as claimed in claim 12.

25

#### Brief Description of the Drawings

One arrangement and method for iterative channel impulse response estimation using noise estimate incorporating  
30 the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIG. 1 shows a prior art arrangement for iterative channel impulse response estimation; and

5 FIG. 2 shows a prior art receiver arrangement for iterative channel impulse response estimation; and

FIG. 3 shows a receiver arrangement for iterative channel impulse response estimation incorporating  
10 the present invention.

#### Description of Preferred Embodiment

15 FIG. 1 shows, in outline, a GSM/EDGE ("Groupe Spéciale Mobile" or General System for Mobile communications/Enhanced Data rates for GSM Evolution) wireless cellular telephone communication system 10 in which the present invention may be used.

20

Generally, the system's air-interface protocol is administered from base transceiver sites that are geographically spaced apart - one base site supporting a cell (or, for example, sectors of a cell).

25

A plurality of subscriber units (MSs) 12-16 communicate over the selected air-interface 18-20 with a plurality of base transceiver stations (BTSs) 22-32. A limited number of MSs 12-16 and BTSs 22-32 are shown for clarity  
30 purposes only. The BTSs 22-32 may be connected to a conventional public-switched telephone network (PSTN) 34

through base station controllers (BSCs) 36-40 and mobile switching centres (MSCs) 42-44.

Each BTS 22-32 is principally designed to serve its  
5 primary cell, with each BTS 22-32 containing one or more transceiver units and communicating 56-66 with the rest of the cellular system infrastructure

Each Base Station Controller (BSC) 36-40 may control one  
10 or more BTSS 22-32, with BSCs 36-40 generally interconnected through MSCs 42-44.

Each MSC 42-44 provides a gateway to the PSTN 34, with MSCs 42-44 interconnected through an operations and  
15 management centre (OMC) 46 that administers general control of the cellular telephone communication system 10, as will be understood by those skilled in the art.

The various system elements, such as BSCs 36-38 and OMC  
20 46, will include control logic 48, 50, 52, with the various system elements usually having an associated memory function 54 (shown only in relation to BSC 38 for the sake of clarity). The memory function 54 typically stores historically compiled operational data as well as  
25 in-call data, system information and control algorithms..

In each MS, receiver performance relies on an estimate of the impulse response of the overall channel which includes the transmitter pulse, the radio channel, and  
30 the receiver selectivity filtering.

Assuming the use of linear or quasi-linear modulations,  
the complex base band received signal may be represented  
as:

$$y(t) = \sum_k a_k \cdot p(t - k \cdot T) + b(t)$$

- 5 where  $\{a_k\}$  is the original transmitted symbol sequence,  
 $p(t)$  represents the complex impulse response of the  
overall channel and  $b(t)$  is the unwanted signal, called  
noise (filtered Gaussian noise, interferers such as upper  
adjacent interferer, lower adjacent interferer, co-  
10 channel interferer, etc.).

The Weighted Least Square algorithm provides for an  
estimate  $\hat{p}(t)$  of  $p(t)$  which minimizes the mean squared  
distance between  $\hat{p}(t)$  and  $p(t)$ . Working with sampled  
15 signals, the generic equation is:

$$\underline{\hat{p}} = (H^H \cdot W \cdot H)^{-1} \cdot H^H \cdot W \cdot \underline{y}$$

where:

$\underline{\hat{p}}$  is the vector of  $L_p$  estimated samples of the overall  
channel.

- 20  $\underline{y}$  is the vector of  $L_y$  received samples corresponding to  
the sequence of known symbols.

$H$  is a  $[L_y, L_p]$  matrix depending on known symbols

$W$  is a  $[L_y, L_y]$  weighting matrix representing the inverse  
of the noise covariance.

25

There is no *a priori* knowledge on the statistical  
properties of the noise which evolves according to the  
position of a mobile station within a cell, according to  
the number of users, and according to the frequency



channel in case of frequency hopping. In most of existing implementations,  $W$  is constant to the benefit of a specific noise (filtered Gaussian noise for instance) or of less complexity when  $W$  is equal to the identity matrix (white Gaussian noise).

Referring now to FIG. 2, a known arrangement 200 for deriving a channel impulse response estimate in a receiver such as MSs 12-16 uses a channel impulse response estimator 210 and an equalizer 220. A received signal is applied to both the equalizer and to the channel impulse response estimator, which is initially trained with a predetermined training sequence. The channel impulse response estimator 210 produces an estimated channel signal which is applied to the equalizer 220, where it is used to produce a tentative decision for modulated symbols in the received signal. The tentative decisions are iteratively fed back to the channel impulse response estimator 210, to modify estimated channel signal so as to improve the tentative symbol decisions.

However, this known approach has the disadvantage that a great part of the complexity of the technique depends on the complexity of the equalizer 220, which may dramatically increase with the number of points in the modulation constellation.

Referring now to FIG. 3, an arrangement 300 for improving the quality of the overall channel impulse response estimate for use in a receiver such as MSs 12-16 includes a channel impulse response estimator 310 (known per se)



and a noise estimator 320 (whose function will be described in more detail below). A received signal is applied to both the channel impulse response estimator 310 and to the noise estimator 320; both the channel impulse response estimator 310 and the noise estimator 320 are initially trained with a predetermined training sequence. The channel impulse response estimator 310 produces an estimated channel signal which is applied to the noise estimator 320 and to a further stages such as an equalizer (not shown) where it is used to produce decisions for modulated symbols in the received signal. The noise estimator 320 produces parameters depending on noise in the received signal; these parameters are applied to further stages (not shown) and are also fed back to the channel impulse response estimator 310, to modify the estimated channel signal so as to improve symbol decisions.

In this technique, channel impulse response estimation is done by iterations. Each iteration provides updated knowledge about statistical properties of the noise and updated channel impulse response estimate. A first estimate of the channel is fed to the noise estimator 320 which estimates the noise parameters which are then provided to the channel impulse response estimator which estimates the channel and so on. The sequence of operations of the method is detailed below:

### 30 *Initialisation*

The first estimate of the channel impulse response  $\underline{p(0)}$  can be computed by using an *a priori* weighting matrix or by using a correlation method which is widely used for GSM training sequences

5

Iteration  $K$  for  $K > 0$

The vector of noise samples  $\underline{b(K)}$  is given by:

$$\underline{b(K)} = \underline{y} - H \cdot \underline{p(K-1)}$$

10 Then  $\underline{r(K)}$ , the vector of  $L$ , noise covariance taps, is computed from the estimated noise samples:

$$\underline{r(K)} = \text{win}_k \cdot \sum_{l=k}^{L_y-1} b_l(K) \cdot b_{l-k}(K)^*$$

where  $\text{win}_k$  is a windowing function with a positive Fourier transform.

15

Then the new channel impulse response estimate is given by:

$$\underline{p(K)} = (H^H \cdot W(K) \cdot H)^{-1} \cdot H^H \cdot W(K) \cdot \underline{y}$$

where  $W(K)$  is the new weighting matrix.

20

For the computation of equation members including  $W(K)$ , two modes of computation are possible:

- mode A: on the fly.
  - mode B: precomputed values which correspond to the statistics of the expected noises (e.g., Gaussian noise, upper adjacent interferer noise, lower adjacent interferer noise, or co-channel interferer noise).
- 25

In mode A, the  $[L_y, L_y]$  matrix  $W(K)$  is given by :

$$W(K) = \begin{bmatrix} r_0(K) & r_1(K) & \dots & r_{L_r-1}(K) & 0 & \dots & 0 \\ r_1(K)^* & r_0(K) & \dots & r_{L_r-2}(K) & r_{L_r-1}(K) & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ r_{L_r-1}(K)^* & r_{L_r-2}(K)^* & \dots & \dots & \dots & \dots & \dots \\ 0 & r_{L_r-1}(K)^* & r_{L_r-2}(K)^* & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & r_1(K) \\ 0 & 0 & 0 & \dots & \dots & r_1(K)^* & r_0(K) \end{bmatrix}^{-1}$$

In mode B, the vector  $\underline{r(K)}$  is compared with a set of  $N$ ,  
5 expected vectors  $\underline{r^M}$  and the  $[L_y, L_y]$  matrix  $W(K)$  is given  
by:

$$W(K) = W^{M_{opt}} = \begin{bmatrix} r_0^{M_{opt}} & r_1^{M_{opt}} & \dots & r_{L_r-1}^{M_{opt}} & 0 & \dots & 0 \\ r_1^{M_{opt}*} & r_0^{M_{opt}} & \dots & r_{L_r-2}^{M_{opt}} & r_{L_r-1}^{M_{opt}} & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ r_{L_r-1}^{M_{opt}*} & r_{L_r-2}^{M_{opt}*} & \dots & \dots & \dots & \dots & \dots \\ 0 & r_{L_r-1}^{M_{opt}*} & r_{L_r-2}^{M_{opt}*} & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & r_1^{M_{opt}} \\ 0 & 0 & 0 & \dots & \dots & r_1^{M_{opt}*} & r_0^{M_{opt}} \end{bmatrix}^{-1}$$

where  $M_{opt}$  is the index of the vector which minimizes the  
10 distance between  $\underline{r(K)}$  and  $\underline{r^M}$ .

It will be understood that the technique for iterative  
channel impulse response estimation using noise estimate  
described above provides the following advantages:

- 15
- Less complexity;
  - Independence of the particular equalization method;
- and

- Consequent performance improvement (tests have shown that use of this technique in a EDGE system can result in a performance improvement of 1.8dB).

- 5 It will be understood that, if desired, the technique for iterative channel impulse response estimation using noise estimate described above could be with the prior art technique of FIG. 2.
- 10 It will also be understood that, although the technique for iterative channel impulse response estimation using noise estimate has been described above in relation to the receiver in a mobile station (MS), the technique could also be applied to the receiver in a base station
- 15 (BTS).

It will be appreciated that the method described above for iterative channel impulse response estimation using noise estimate will typically be carried out in software

20 running on a processor (not shown), and that the software may be provided as a computer program element carried on any suitable data carrier (also not shown) such as a magnetic or optical computer disc.

- 25 It will also be appreciated that various modifications to the embodiment described above will be apparent to a person of ordinary skill in the art.

## Claims

1. An arrangement, for iterative channel impulse response estimation in a system employing a transmission  
5 channel, comprising:

channel impulse response estimation means for producing from a received signal a channel impulse response estimate signal; and noise estimation means for producing from the  
10 received signal a noise estimate signal, the channel impulse response estimation means being arranged to iteratively receive the noise estimate signal and to iteratively produce in dependence thereon an improved channel impulse response  
15 estimate signal.

2. The arrangement of claim 1 wherein the noise estimate signal comprises a matrix representing the inverse of noise covariance.  
20

3. The arrangement of claim 2 wherein the matrix representing the inverse of noise covariance is calculated at each iteration.

- 25 4. The arrangement of claim 2 wherein the matrix representing the inverse of noise covariance is selected from predetermined values corresponding to statistics of expected noise.

- 30 5. The arrangement of claim 2, 3 or 4 wherein the channel impulse response estimate signal is represented by:

$$(H^H \cdot W \cdot H)^{-1} \cdot H^H \cdot W \cdot \underline{y},$$

where  $H$  represents a matrix depending on known symbols,  
 $\underline{y}$  represents a vector of received channel samples, and  $W$   
represents the inverse noise covariance matrix.

5

6. The arrangement of claim 5 when dependent on claim 4  
wherein the predetermined values corresponding to  
statistics of expected noise are selected according to  
the noise types: Gaussian, upper adjacent interferer,  
10 lower adjacent interferer, or co-channel interferer.

7. The arrangement of any preceding claim wherein the  
channel impulse response estimation means is arranged to  
produce the channel impulse response estimate signal as a  
15 weighted least square function.

8. The arrangement of any preceding claim wherein the  
system is a wireless communication system.

20 9. The arrangement of claim 8 wherein the system is a  
GSM system.

10. The arrangement of claim 9 wherein the system is an  
EDGE system.

25

11. A receiver for use in a system employing a  
transmission channel, the receiver comprising the  
arrangement of any preceding claim.

12. A method, for iterative channel impulse response estimation in a system employing a transmission channel, comprising:

5 providing channel impulse response estimation means for producing from a received signal a channel impulse response estimate signal; and  
providing noise estimation means for producing from the received signal a noise estimate signal,  
the channel impulse response estimation means  
10 iteratively receiving the noise estimate signal and iteratively producing in dependence thereon an improved channel impulse response estimate signal.

13. The method of claim 12 wherein the noise estimate  
15 signal comprises a matrix representing the inverse of noise covariance.

14. The method of claim 13 wherein the matrix  
representing the inverse of noise covariance is  
20 calculated at each iteration.

15. The method of claim 13 wherein the matrix  
representing the inverse of noise covariance is selected  
from predetermined values corresponding to statistics of  
25 expected noise.

16. The method of claim 13, 14 or 15 wherein the channel impulse response estimate signal is represented by:

$$(H^H \cdot W \cdot H)^{-1} \cdot H^H \cdot W \cdot \underline{y},$$



where  $H$  represents a matrix depending on known symbols,  $\underline{y}$  represents a vector of received channel samples, and  $\underline{W}$  represents the inverse noise covariance matrix.

- 5 17. The arrangement of claim 16 when dependent on claim 15 wherein the predetermined values corresponding to statistics of expected noise are selected according to the noise types: Gaussian, upper adjacent interferer, lower adjacent interferer, or co-channel interferer.
- 10 18. The method of any one of claims 12-17 wherein the channel impulse response estimation means produces the channel impulse response estimate signal as a weighted least square function.
- 15 19. The method of any one of claims 12-18 wherein the system is a wireless communication system.
- 20 20. The method of claim 19 wherein the system is a GSM system.
21. The method of claim 20 wherein the system is an EDGE system.
- 25 22. A computer program element comprising computer program means for performing the method of any one of claims 12-21.

**BEST AVAILABLE COPY**

**Abstract**

ARRANGEMENT AND METHOD FOR ITERATIVE CHANNEL IMPULSE  
RESPONSE ESTIMATION

5

An arrangement (300) and method, for iterative channel impulse response estimation in a system such as a GSM/EDGE system employing a transmission channel, by: producing (310) from a received signal ( $y$ ) a channel impulse response estimate signal ( $\hat{p}$ ); and producing (320) from the received signal ( $y$ ) a noise estimate signal ( $W$ ) which is iteratively fed back to improve the channel impulse response estimate signal ( $\hat{p}$ ). The noise estimate signal may comprise a matrix ( $W$ ) representing the inverse of noise covariance; the matrix may be calculated at each iteration or may be selected from predetermined values corresponding to statistics of expected noise.

15

20 This provides the advantages of reduced complexity, independence of the equalization method used to produce the channel impulse response estimate signal, and consequent performance improvement.

25 (FIG. 3)

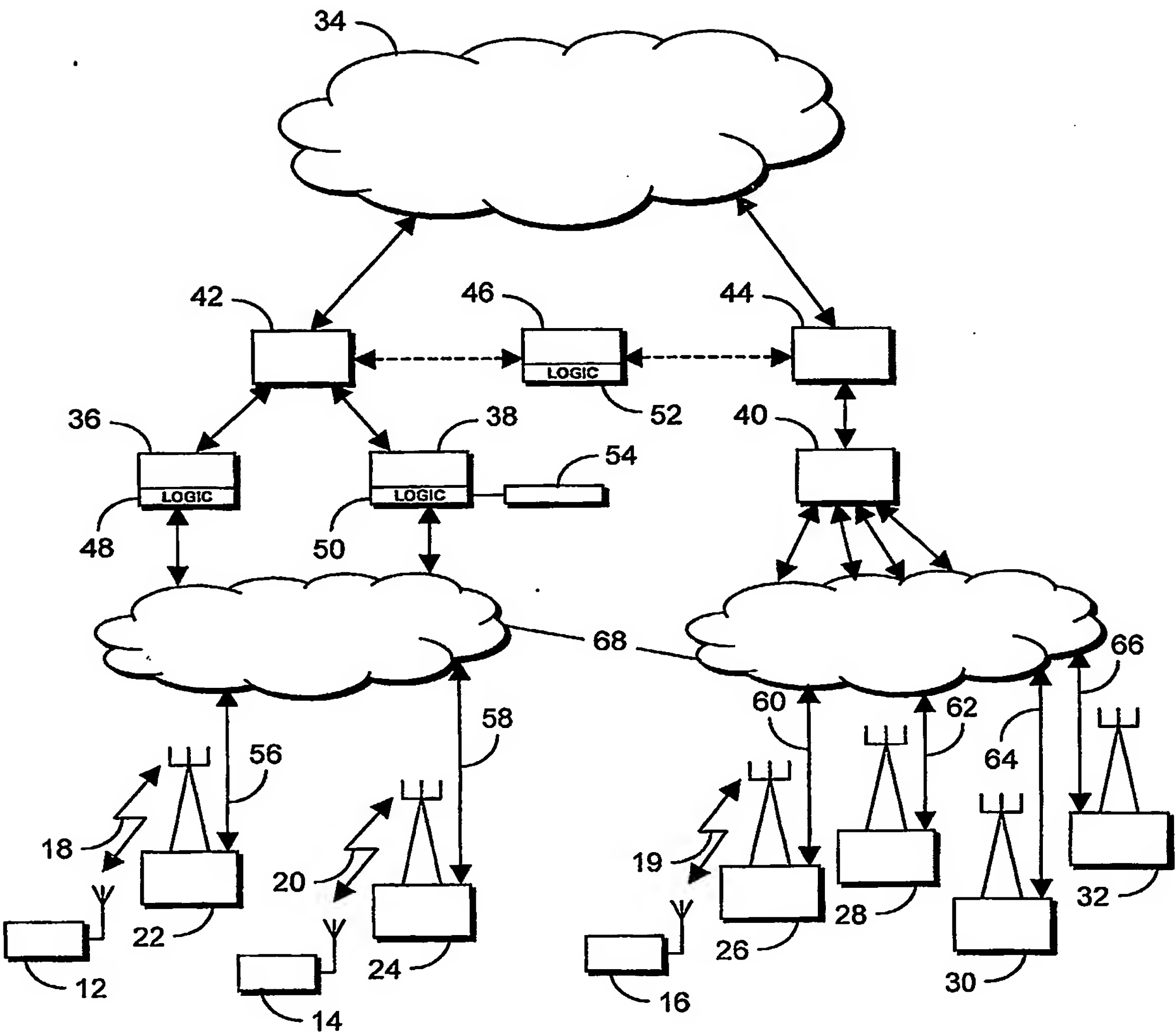
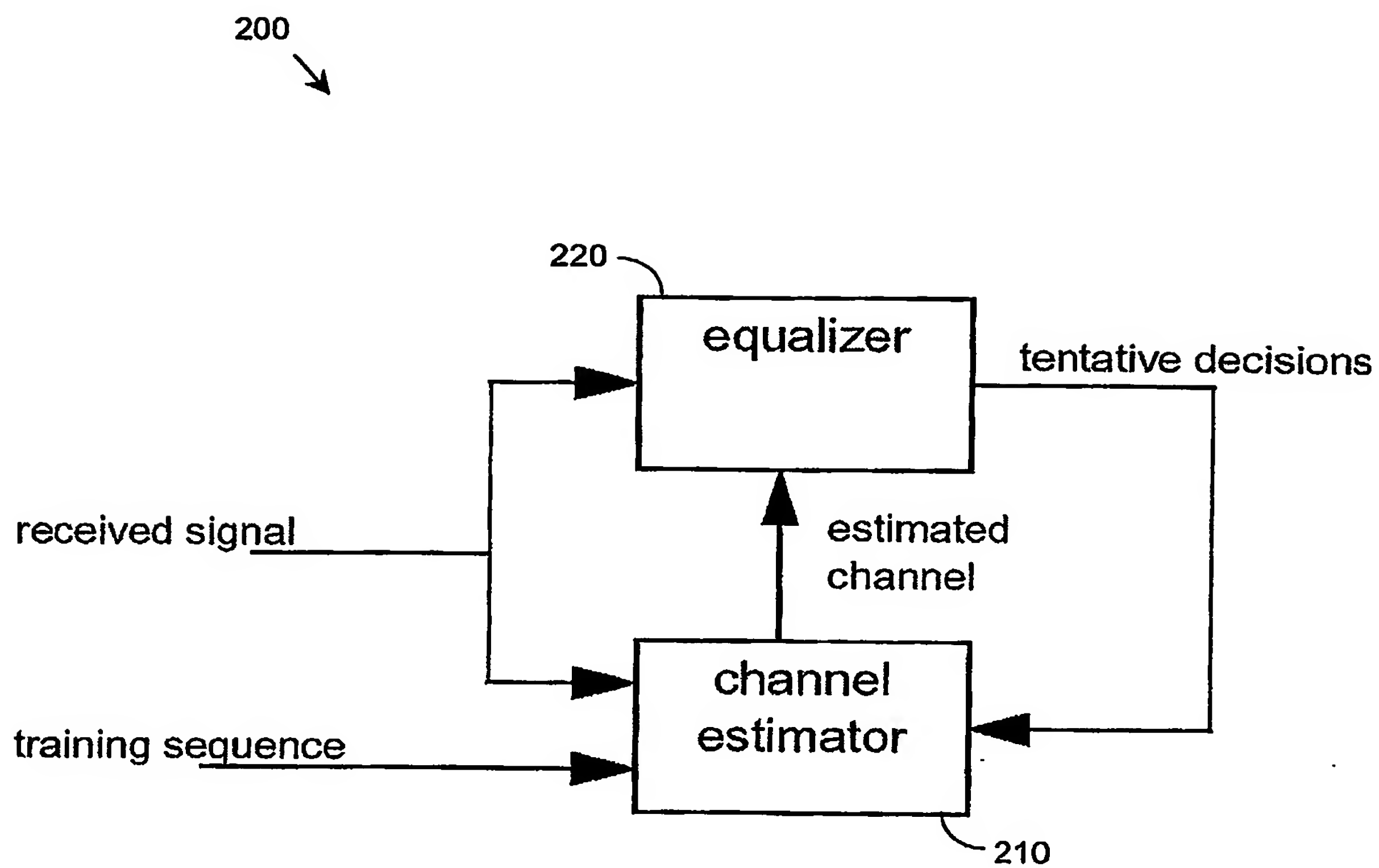


FIG. 1



**FIG. 2**  
**PRIOR ART**

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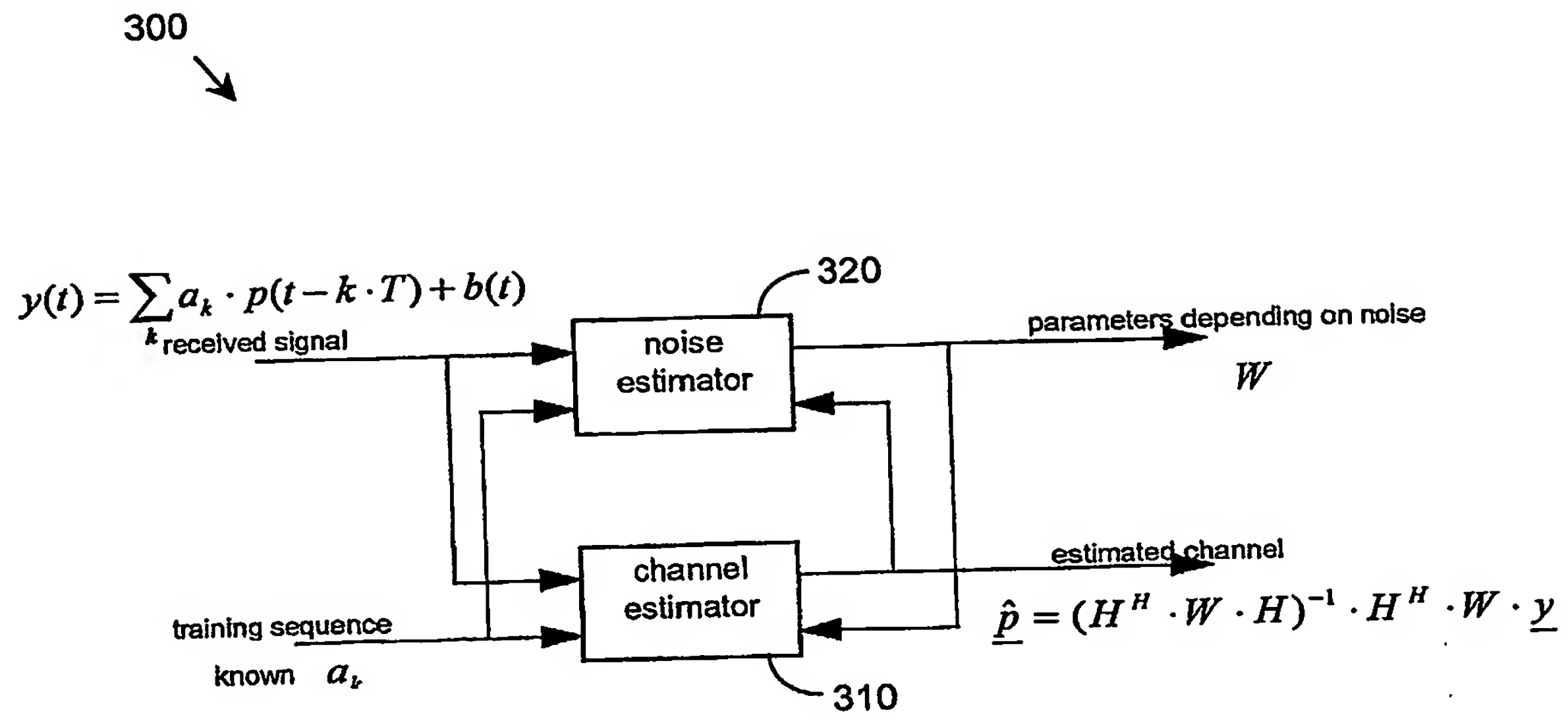


FIG. 3